inverter. It would therefore be desirable to have a permanent magnet alternator with high voltage direct current output so that an inverter without voltage boost could be utilized.

Summary of the Invention

The present invention solves the problems of the prior art wind turbines by utilizing a novel power electronic controller. The controller uses a power electronics bridge to provide power control and active rectification. The controller uses boost mode techniques to control the alternator. The boost mode allows optimized performance in low winds and provides for aerodynamic stall in high winds.

The controller consists of a rectifier that utilizes a switching device, such as an FET or an IGBT, on each phase along with at least one diode on each phase. The switching devices short the phases together for a short period of time to allow energy storage within the internal inductance of the alternator. When the switches reopen, the energy stored in the alternator's inductance is released and the output voltage is temporarily boosted. This technique is commonly employed with external inductors used for energy storage. The present invention utilizes the internal inductance of the alternator, rather than an external inductor, to achieve boost mode.

The controller can be used to regulate the voltage of the alternator's output so that a separate voltage regulator is not required. If the wind turbine is connected to a battery bank, the controller can monitor the batteries' voltage and regulate the alternator's output voltage appropriately to achieve efficient battery charging. If the alternator is used with an inverter in an AC application, then the controller can be used to raise the output voltage of the alternator so that the boost portion of the inverter is not required. This

simplifies the design of the inverter and improves the economics of grid-connected wind energy conversion.

One advantage of utilizing boost mode in a wind turbine with a permanent magnet alternator is that it improves the wind turbine's performance in low winds. The controller monitors the turbine's rotor speed and, when a sufficient speed is reached to allow generation, the switches on all of the phases are momentarily shorted to cause an inductive voltage spike in the alternator's windings that causes current to begin flowing. The boost mode also raises the output voltage of the alternator to a level that is useful for battery charging even when the rotor is turning at slow speeds.

The boost mode controller can create an audible acoustic noise at the switching frequency of the FETs or IGBTs. The noise is created by abrupt changes in current in the alternator's stator windings. When the boost mode controller is activated at low wind speeds to enhance the low wind operating characteristics of the wind turbine, its acoustic noise can stand out above the aerodynamic noise created by the wind turbine. The noise can be particularly noticeable if it is at a constant frequency because the noise is tonal whereas aerodynamic noise is atonal. In order to overcome this issue, the switching frequency of the FETs or IGBTs is constantly varied. Varying the switching frequency causes the noise from the alternator to be atonal and makes it much less noticeable.

At high wind speeds, the boost mode controller can be used to increase the reaction torque in the alternator. This allows the wind turbine's rotor to be slowed in high winds, thereby inducing aerodynamic stall. In this manner, a permanent magnet alternator can be used in a wind turbine that has variable speed operation and power control by aerodynamic stall.

Brief Description of the Drawings

Other features and advantages of the invention will be apparent from the following Detailed Description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a wind turbine according to the present invention.

FIG. 2 is an exploded view of a wind turbine according to the present invention.

FIG. 3 is a rectifier circuit according to the prior art.

FIG. 4 is a block diagram of the wind turbine controller of the present invention.

FIG. 5 is circuit diagram for the wind turbine controller according to a first embodiment of the present invention.

FIG. 6 is circuit diagram for the wind turbine controller according to a second embodiment of the present invention.

FIG. 7 shows the output voltage, current, and power from the wind turbine controller of the present invention.

FIG. 8 shows the output voltage, current, and power from the wind turbine controller of the present invention with a lower switching frequency compared to FIG. 7.

FIG. 9 shows an operating map of duty cycle versus rotor speed for the wind turbine controller of the present invention.

FIG. 10 is a flow chart for the control strategy used in the preferred embodiment of the wind turbine controller of the present invention.

Detailed Description of the Invention

Figure 1 shows a wind turbine 2 with three blades 4, a nacelle 6, and a tower 8. While the wind turbine 2 is shown with three blades 4, the present invention can work on